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- (54) Title: USES OF VASCULAR ENDOTHELIAL GROWTH FACTOR IN THE TREATMENT OF ERECTILE DYSFUNCTION
(54) Titre: UTILISATIONS DU FACTEUR DE CROISSANCE VASCULAIRE ENDOTHELIALE POUR LE TRAITEMENT DE LA DYSERECTION

(57) Abstract

This invention provides a method of increasing or maintaining the blood supply in the penis of a male subject which comprises administering to the subject an amount of vascular endothelial growth factor effective to increase or maintain the blood supply in the subject's penis. This invention provides a method of treating erectile dysfunction in a subject which comprises administering to the subject an amount of vascular endothelial growth factor effective to increase the blood supply in the subject's penis and thereby treat the subject's erectile dysfunction. This invention provides a method of increasing or maintaining the blood supply in the penis of a subject which comprises introducing a nucleic acid comprising a gene encoding a vascular endothelial growth factor into a suitable cell under conditions such that the nucleic acid expresses vascular endothelial growth factor so as to thereby increase or maintain the blood supply in the subject's penis. This invention provides a method of increasing or maintaining the blood supply in the genital area of a female subject which comprises administering to the subject an amount of vascular endothelial growth factor effective to increase or maintain the blood supply in the subject's genital area.

(57) Abrégé

L'invention concerne un procédé permettant d'augmenter ou d'entretenir l'irrigation sanguine du pénis chez un sujet mâle et consistant en l'administration à ce sujet d'une quantité suffisante de VEGF (Vascular Endothelial Growth Factor) ou "facteur de croissance vasculaire endothéliale" pour augmenter ou entretenir l'irrigation sanguine du peins du sujet. L'invention concerne un procédé permettant de traiter la dysérection chez un sujet, et consistant en l'administration au sujet d'une quantité de VEGF suffisante pour augmenter l'irrigation sanguine du pénis du sujet et ainsi de traiter la dysérection du sujet. L'invention concerne un procédé permettant d'augmenter ou d'entretenir l'irrigation sanguine du pénis chez un sujet mâle et consistant en l'introduction d'un acide nucléique comprenant un gène codant pour un VEGF introduit dans une cellule appropriée dans des conditions telles que l'acide nucléique vienne exprimer le VEGF de façon à augmenter ou entretenir l'irrigation sanguine du pénis du sujet. L'invention concerne un procédé permettant d'augmenter ou d'entretenir l'irrigation sanguine de la sphère génitale d'un sujet femelle et consistant en l'administration à ce sujet d'une quantité de VEGF suffisante pour augmenter l'irrigation sanguine de la sphère génitale du sujet.

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Description

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USES OF VASCULAR ENDOTHELIAL GROWTH
FACTOR IN THE TREATMENT OF ERECTILE DYSFUNCTION

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5 This application claims priority of U.S. Serial No. 09/234,591, filed January 21, 1999, the contents of which is hereby incorporated by reference.

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Throughout this application, various publications are referenced by Arabic numerals. Full citations for these publications may be found at the end of the specification immediately preceding the claims. The disclosure of these publications is hereby incorporated by reference into this application to describe more fully the art to which this invention pertains.

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Background of the Invention

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Mammalian reproduction requires a physiological stimulation of male erectile tissues in the penis to mechanistically support the transfer of sperm from the male to the female. Obviously then, defects that prevent an appropriate erectile tissue response can drastically interfere with reproductive capability. In humans, erectile dysfunction is considered to be a disease state and is referred to as the condition of "impotence". This condition impacts on the quality of life both of the male patients, as well as their wives/partners (1).

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Erection is a hemodynamic phenomenon involving the tissue of the corpora cavernosa as well as the corpus spongiosum in the penis. This tissue is a complex admixture of smooth muscle, endothelial cells, fibroblasts and nerves interacting under stimulatory conditions to drastically enhance and maintain an accessory blood supply that imparts rigidity to the penis. Given the need for stringent control of blood flow during this response, it is no surprise that vascular insufficiency has the ability to drastically suppress erectile capability. In fact, penile vascular insufficiency is believed to be a very common pathomechanism of erectile dysfunction (2). This

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5 is associated with substantial pathologic changes in the
erectile tissue leading to reduction in vascular smooth
muscle cells and increases in collagen and fibrosis (3-6).

10 5 The currently available treatments of erectile dysfunction
induce temporary erections at the same time of administration
of such treatments. However, these treatments do not address
15 or cure the basic vascular/cavernosal pathology causing
erectile dysfunction. The rationale for a curative treatment
10 that improves or repairs the vascular structure and function
of the erectile tissue is based upon the understanding of
erectile physiology and the pathophysiology of vascular
20 erectile dysfunction. Consequently, it is prudent to pursue
investigation of factors that induce new vascular structure
15 formation or vasculogenesis. Several naturally occurring
growth factors have been found to induce vasculogenesis
25 (7-10). Such growth factors include the vascular endothelial
growth factor (VEGF) family (11), the fibroblast growth
factor (FGF) family (12,13), transforming growth factor
20 -alpha and -beta (TGF) (14), and platelet derived growth
factor (PDGF) (15-17). Vascular endothelial growth factor
30 (VEGF) may well be one of the most potent and interesting of
these vascular growth factors. It is thought to play a role
in embryonic vasculogenesis (18), maintenance of vascular
35 structures in the adult and formation of new blood vessels
in the adult in responses to ischemia and other pathologic
states. Therapies that increase tissue levels of VEGF in
laboratory animals or humans with peripheral vascular disease
40 have resulted in a measurable increase in tissue vascularity
30 (19-24).

45 In order to contemplate the potential of VEGF therapy for
erectile dysfunction, a characterization was wanted of the
extent to which VEGF is expressed in the mammalian penis and
35 in erectile tissue, as well as a determination of which of
the known isoforms of VEGF (derived from mRNA splice site
variation) are most abundantly present in this tissue
50 compared to other mammalian tissues. Here a survey of VEGF

5 isoform expression (mRNA) in mature rat penis and in human
erectile tissue is presented.

10 VEGF is a growth factor that acts preferentially on
5 endothelial cells(18). With the current focus of biomedical
research on angiogenesis, the biology of VEGF has been under
intense scrutiny. In humans, there are several different
15 genes that encode VEGF-like proteins (49,50), the most
studied of these genes is that for VEGF-A (51,52,53). As
10 described by several different laboratories, the VEGF-A gene
gives rise to several different mature mRNA transcripts that
differ in the protein products they encode (33,34). These
20 variant transcripts arise through an alternative splicing
mechanism (30,31,54) and the abundance of any particular
15 VEGF-A transcript differs, depending on the tissue examined
(28). The most predominant VEGF-A transcripts found in adult
25 tissues encode proteins of 188/189, 164/165 and 120/121 amino
acids (rat/human) (28,35). Other, rarer variant transcripts
arising from VEGF-A have also been reported (encoding 205/206
20 and 144/145 amino acid proteins), but these forms were only
found in a few tissues, mainly fetal in origin (VEGF 205/206:
30 human fetal liver (32), sheep (41) and human placenta (42)/
VEGF 144/145: human uterus (39), human endometrial carcinoma
cells (39), sheep (41) and human placenta (42),
35 respectively). During a preliminary survey of adult penile
tissues for the expression of VEGF-A isoforms, it was found
that the expression of VEGF-A mRNA splice variants encoding
the 205/206 and 144/145 forms of VEGF can be identified by
40 standard RT-PCR techniques and confirmed by cloning and
30 sequencing from other adult rat and human tissues and
cultured cells. These results suggest that these rarer
splice variants of VEGF-A might have a wider tissue
45 distribution than originally anticipated.

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Summary of the Invention:

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This invention provides a method of increasing or maintaining the blood supply in the penis of a male subject which comprises administering to the subject an amount of vascular endothelial growth factor effective to increase or maintain the blood supply in the subject's penis.

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This invention provides a method of treating erectile dysfunction in a subject which comprises administering to the subject an amount of vascular endothelial growth factor effective to increase the blood supply in the subject's penis and thereby treat the subject's erectile dysfunction.

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This invention provides a method of increasing or maintaining the density of vascular structures in the penis of a male subject which comprises administering to the subject an amount of vascular endothelial growth factor effective to increase or maintain the blood supply in the subject's penis.

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This invention provides the above methods, wherein the vascular endothelial growth factor is VEGF-A 205/206, VEGF-A 188/189, VEGF-A 164/165, VEGF-A 144/145, VEGF-A 120/121, or VEGF-A 110.

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This invention provides the above methods, wherein the vascular endothelial growth factor is administered intravenously, topically, transdermally, orally or by injection.

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This invention provides the above methods, wherein the vascular endothelial growth factor is injected into the penis.

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This invention provides the above methods, wherein the vascular endothelial growth factor is injected into corpora cavernosa or corpus spongiosum tissue.

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This invention provides a method of increasing or maintaining

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the blood supply in the penis of a subject which comprises introducing a nucleic acid comprising a gene encoding a vascular endothelial growth factor into a suitable cell under conditions such that the nucleic acid expresses

10 5 vascular endothelial growth factor so as to thereby increase or maintain the blood supply in the subject's penis.

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This invention provides a method of increasing or maintaining the blood supply in the genital area of a female subject

10 15 which comprises administering to the subject an amount of vascular endothelial growth factor effective to increase or maintain the blood supply in the subject's genital area.

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Brief Description of the Figures:

Figure 1

Diagram characterizing some major VEGF-A cDNA splice variants isoforms that were previously detected in rat tissues and were also observed in the study:

The mammalian VEGF gene is split into eight exons (represented by boxes). Alternative splicing of these exons give rise to six molecular forms previously detected in rat tissues (VEGF 205 amino acids - 120 amino acids) as well as a form (VEGF 110 amino acids) that was discovered by our screening and sequencing of VEGF cDNA clones from the rat penis. The nucleotide length of the exon boxes is described above the VEGF 205 form and below the VEGF 110 form.

Figure 2

RT-PCR characterization of VEGF-A cDNA splice variants expressed in rat and human tissues:

(A) Agarose gel profile of products resulting from RT-PCR amplification of VEGF-A mRNA splice variants present in rat tissues. Both rat lung and penis show presence of cDNA products characteristic of amplification of VEGF-A splice forms 188, 164, 144 and 120. These cDNA amplification products migrate equivalently with the characterized VEGF isoform markers present individually in the lanes on the right as marked. Whereas 188 form appears to more predominant in lung, the 164 form appears to be most abundant in penis. M.W. = lanes containing molecular weight markers.

(B) Agarose gel profile of products resulting from RT-PCR amplification of VEGF-A mRNA splice variants present in human cells and tissue. Both the LNCaP cell line RNA and human cavernosal RNA allow the amplification of 4 major splice variants of VEGF A (189, 165, 145 and 121). As with the results from amplification of rat penis RNA (4th lane), the 165 AA splice variant is more abundant in human penis than the 189 splice variant. Similarly amplified products from rat tissues (penis and lung) are compared on right

lanes. M.W. = Lane containing molecular weight marker. Molecular sizes of amplified fragments are shown on the right.

Figure 3
RNase protection assays of RNAs extracted from rat lung or
penis to measure relative abundance of VEGF-A mRNA splice
variant expression:

- (A) RNase protection assay using 32P-labeled large (VEGF 188) antisense riboprobe. Autoradiograph of gel containing RNase digestion products reveals the presence of a protected 564 bp fragment characterizing abundant expression of VEGF 188 splice variant only in rat lung, not in rat penis mRNA.
- (B) RNase protection assay using 32P-labeled small (VEGF 164) antisense riboprobe. Autoradiograph of gel containing RNase digestion products reveals the presence of abundant 150 bp protected fragment in lung, not penis RNA, confirming abundant expression of 188 splice variant in this site. Likewise the presence of a 492 bp protected fragment in both rat lung and penis RNA characterizes expression of the VEGF 164 splice isoform in both tissues. Finally, the presence of 342 bp protected fragment in penis RNA, while potentially resulting from hybridization with the 188 or 144 splice forms, is most likely to result from the digestion of an abundant VEGF 120 splice isoform in the penis based on our inability to detect protection of the other specific fragments that would result from hybridization of the large (VEGF 188) probe with the 188 or 144 splice variants. Diagrams (at lower part of figures) identify the size of potential protected fragments that could result using the larger probe (A) or the smaller VEGF probe (B). Sizes of molecular weight markers (M.W.) are indicated to the right, sizes of specifically designated protected fragments are indicated to the left. Control lanes include yeast RNA hybridized to probe + digestion or

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yeast RNA hybridized to probe - digestion.

Figure 4

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RT-PCR amplification demonstrates VEGF splice isoform
(144/145) expression in rat and human tissues and cells:

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PCR primers within exon 1 and 8 of VEGF-A were used to amplify cDNA from rat lung and penis or from human penis or LNCaP cell lines. Agarose gel of reaction products stained with ethidium bromide. Arrows show position of bands at 360/363 bp (VEGF 120/121), 432/435 bp (VEGF 144/145), 492/495 bp (VEGF 164/165) and 564/567 bp (VEGF 188/189).

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Right side of gel contains a representative ladder generated by PCR-amplification of individual clones containing the referenced VEGF cDNA fragment or a molecular

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weight marker (M.W.)

Figure 5

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RT-PCR amplification demonstrates VEGF splice isoform (VEGF
205) expression in rat tissues:

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20 PCR primers within exon 1 and 6B of VEGF-A were used to amplify cDNA from adult rat lung and penis. Agarose gel of reaction products stained with ethidium bromide. Arrow show position of bands at 433bp (VEGF 205). Right lanes contain RT-PCR reaction products using exon 1/8 primers on rat tissues or cloned plasmids containing defined splice variant cDNA for VEGF-A as indicated. M.W. is a molecular weight marker.

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Detailed Description of the Invention

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This invention provides a method of increasing or maintaining the blood supply in the penis of a male subject which comprises administering to the subject an amount of vascular endothelial growth factor effective to increase or maintain the blood supply in the subject's penis.

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10 As used herein, "increasing" means that the blood supply is at a level that is higher than that which would exist in a control experiment without using said method.

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As used herein, "maintaining" means that the blood supply is kept at a level which is greater than or equal to the blood supply that exists in a control situation without using said method.

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As used herein, "subject" includes any animal or artificially modified animal. This includes but is not limited to animals such as mice, rats, dogs, guinea pigs, ferrets, rabbits, primates, equine, bovine, avian, caprine, canine, feline. As used herein, "subject" also includes a human. In the preferred embodiment, the subject is human.

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25 This invention provides a method of treating erectile dysfunction in a subject which comprises administering to the subject an amount of vascular endothelial growth factor effective to increase the blood supply in the subject's penis and thereby treat the subject's erectile dysfunction.

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As used herein, "treating" means either slowing, stopping or reversing erectile dysfunction. In the preferred embodiment, treating means reversing to the point of eliminating erectile dysfunction.

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This invention provides a method of increasing or maintaining the density of vascular structures in the penis of a male

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5 subject which comprises administering to the subject an amount of vascular endothelial growth factor effective to increase or maintain the blood supply in the subject's penis.

10 5 This invention provides the above methods, wherein the vascular endothelial growth factor is VEGF-A 205/206, VEGF-A-188/189, VEGF-A 164/165, VEGF-A 144/145, VEGF-A 120/121, or VEGF-A 110.

15 10 As used herein, "VEGF-A 205/206" refers to the VEGF-A rat 205 amino acid splice variant or VEGF-A human 206 amino acid splice variant.

20 As used herein, "VEGF-A 188/189" refers to the VEGF-A rat 188 amino acid splice variant or VEGF-A human 189 amino acid splice variant.

25 As used herein, "VEGF-A 164/165" refers to the VEGF-A rat 164 amino acid splice variant or VEGF-A human 165 amino acid splice variant.

30 As used herein, "VEGF-A 144/145" refers to the VEGF-A rat 144 amino acid splice variant or VEGF-A human 145 amino acid splice variant.

35 25 As used herein, "VEGF-A 120/121" refers to the VEGF-A rat 120 amino acid splice variant or VEGF-A human 121 amino acid splice variant.

40 30 As used herein, "VEGF-A 110" refers to the VEGF-A human 110 amino acid splice variant.

45 This invention provides the above methods, wherein the vascular endothelial growth factor is administered intravenously, topically, transdermally, orally or by injection.

50 This invention provides the above methods, wherein the

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vascular endothelial growth factor is injected into the penis.

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This invention provides the above methods, wherein the vascular endothelial growth factor is injected into corpora cavernosa tissue.

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This invention provides the above methods, wherein the vascular endothelial growth factor is injected into corpus spongiosum tissue.

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This invention provides a method of increasing or maintaining the blood supply in the penis of a subject which comprises introducing a nucleic acid comprising a gene encoding a vascular endothelial growth factor into a suitable cell under conditions such that the nucleic acid expresses vascular endothelial growth factor so as to thereby increase or maintain the blood supply in the subject's penis.

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As used herein, the term "nucleic acid," refers to either DNA or RNA. "Nucleic acid sequence" or "polynucleotide sequence" refers to a single- or double-stranded polymer of deoxyribonucleotide or ribonucleotide bases read from the 5' to the 3' end. It includes both self-replicating plasmids, infectious polymers of DNA or RNA and nonfunctional DNA or RNA.

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As used herein, "suitable" means a cell which can express the vascular endothelial growth factor gene such that it produces vascular endothelial growth factor to thereby increase or maintain the blood supply in the subject's penis.

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The term "vector", refers to viral expression systems, autonomous self-replicating circular DNA (plasmids), and includes both expression and nonexpression plasmids. Where a recombinant microorganism or cell culture is described as hosting an "expression vector," this includes both extrachromosomal circular DNA and DNA that has been

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5 incorporated into the host chromosome(s). Where a vector is
being maintained by a host cell, the vector may either be
10 stably replicated by the cells during mitosis as an
autonomous structure, or is incorporated within the host's
5 genome.

15 This invention provides the above method, wherein the nucleic
acid comprises a vector.

20 As used herein, "vector" includes viral expression systems,
autonomous self-replicating circular DNA plasmids and
includes both expression and nonexpression plasmids.

25 This invention provides a method of increasing or maintaining
the density of vascular structures in the penis of a subject
which comprises introducing a nucleic acid comprising a gene
25 encoding a vascular endothelial growth factor into a suitable
cell under conditions such that the nucleic acid expresses
vascular endothelial growth factor so as to thereby increase
20 or maintain the blood supply in the subject's penis.

30 This invention provides a method of increasing or maintaining
the blood supply in the genital area of a female subject
which comprises administering to the subject an amount of
35 25 vascular endothelial growth factor effective to increase or
maintain the blood supply in the subject's genital area.

40 This invention provides a method of increasing or maintaining
the density of vascular structures in the genital area of a
30 female subject which comprises administering to the subject
an amount of vascular endothelial growth factor effective to
increase or maintain the blood supply in the subject's
45 genital area.

50 35 This invention will be better understood from the
Experimental Details which follow. However, one skilled in
the art will readily appreciate that the specific methods and
results discussed are merely illustrative of the invention

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as described more fully in the claims which follow
thereafter.

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Experimental Details

A. Materials and Methods

1. Human Tissues

5 Specimens of cavernosal tissue of (12) humans (ages 39 -79) were surgically removed from the penoscrotal junction at the time of penile prosthesis implantation under an IRB-approved protocol. These biopsies measured approximately 5x5x10 mm. The specimens were immediately frozen under liquid nitrogen and were stored at -70°C until processing.

2. Laboratory Animals and Tissues

Age-matched male Sprague Dawley rats (8 weeks, Camm Laboratories, Camden, New Jersey), were obtained under an IACUC approved protocol and were maintained on a 12 hour daylight cycle with food and water available ad libitum. Rats were sacrificed by a lethal overdose of sodium pentobarbital. Lung and penis were harvested immediately. Penile tissue was obtained through a circular incision made at the corona with subsequent removal of the foreskin and the shaft skin and amputation of the penis. The glans, which contains a significant amount of skin, was also removed. Excess blood was removed by gently blotting the penis on sterile cotton gauze and the specimen was flash frozen in liquid nitrogen and stored at -70°C until use. This procedure provided cryopreserved, deskinmed penile shafts that contained mostly erectile tissue.

3. RNA Extraction

Tissue (pooled penis from 20 rats or pooled 12 human specimens) was first pulverized under liquid nitrogen to a fine powder. Total RNA was isolated from the tissue powder using an RNazol (Tel-Test, Inc., Friendswoods, Tx) extraction procedure following the manufacturers protocol [25,26]. RNA concentration was determined by spectrophotometry at 260 nm, and to ensure the RNA was not degraded, each sample was analyzed by electrophoresis on a 1% denaturing formaldehyde

5 gel. Total RNA was extracted from the prostate carcinoma cell line, LNCaP, using a modification of this procedure [27].

10 4. RT-PCR to Amplify VEGF cDNAs

5 1ug total RNA was used for first-strand cDNA synthesis. The RNA was annealed to 0.5 ug oligo(dT) primer (Gibco BRL, Grand Island, N.Y.) in a volume of 20 ul at 70 °C for 10 min. then chilled on ice quickly for 2 min.. 10 mM dNTPs , 5x 1st strand buffer, 0,1 M dithiothreitol (DTT), 10 U RNase Inhibitor (Gibco BRL), and 200 U Superscript II reverse transcriptase (Gibco BRL) in a final volume of 50 ul were added. The reaction mix was incubated by heating 37°C for 90 min, and the cDNA was stored at -20 C until used.

15 Polymerase chain reaction (PCR) techniques were then used to identify the presence of VEGF isoforms in the RNA samples. Primers used for the amplification assay were slight modifications of those published previously [28]. Because these primers initiate within the first exon and terminate 20 within the eighth exon of VEGF-A, they enable amplification of all the known VEGF splice variants.

The oligonucleotide sequences of the primers used are as follow:

25 Primer 5'
Species human
Location start of exon 1
Nucleotide sequence 5' TGC ACC CAT GGC AGA AGG AGG 3'

30 Primer 3'
Species human
Location end of exon 8
Nucleotide sequence 5' TCA CCG CCT CGG CTT GTC ACA 3'

35 Primer 5'
Species rat
Location start of exon 1
Nucleotide sequence 5' TGC ACC CAC GAC AGA AGG GGA 3'

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Primer	3'
Species	rat
Location	end of exon 8
5 Nucleotide sequence 5' TCA CCG CCT TGG CTT GTC ACA T 3'	

The PCR reaction mix contained 10x reaction buffer (100mM Tris, 500mM KCL, 1.5 mM MgCl₂, pH 8.3), d NTP Mix (10mM each dATP, dGTP, dCTP and dTTP at neutral pH), 100 pmol upstream primer (5'- human/5'- rat), 100 pmol downstream primer (3'-human/3'-rat), 2.5 U Taq DNA polymerase (Boehringer Mannheim Biochemicals, Indianapolis, IN), 10 ul cDNA, and sterile water to 50 ul. PCR was carried out using a DNA Thermal Cycler (Perkin Elmer Cetus, Norwalk, CT) as follows: 94°C for 7 min.; then 35 cycles of denaturation at 94°C for 1 min., annealing and extension at 72°C for 1 min. each. The PCR products (20 ul of lung-rat-/LNCaP- and 35 ul of penis-rat-/penis-human-reaction mix) were analyzed by electrophoresis on a 2 % agarose gel that was subsequently stained with ethidium bromide for visualization of DNA bands. A 100 base pair ladder DNA molecular weight marker was used (Boehringer Mannheim Biochemicals) to provide a size reference for the test reactions.

5. Cloning and Sequencing of RT-PCR products

1ul of penis-rat-PCR products were ligated into the pGEM-T easy Vector DNA and were used to transform DH5- (competent cells. Transformants containing cDNA inserts were characterized for insert size by analysis of Eco RI digested minipreps. A variety of plasmid vectors containing cDNA inserts of different sizes were then sequenced from the double-stranded templates by standard dideoxynucleotide sequencing techniques. These sequences were compared to the human or rat VEGF cDNA sequences present in genbank to identify exon structure.

6. RNase Protection Assay for VEGF mRNA isoforms

Two antisense RNA probes for VEGF cDNA were used. One was in vitro transcribed from an Apa I-digested vector containing the rat VEGF 164 splice isoform cDNA whereas the other was in vitro transcribed from an Apa I-digested vector containing the rat VEGF 188 splice isoform DNA using SP6- polymerase. The in vitro transcription reactions were carried out in the presence of 250 uCi [³²P]-UTP (NEN Life Science Products, Boston, MA) using the reagents provided in an in vitro-transcription kit (MAXIscript, Ambion, Inc., Austin, TX) according to the manufacturer's instructions. Individual labeled antisense probes (619 bases for the VEGF 164 probe and 691 bases for the VEGF 188 probe) were purified by electrophoresis on a denaturing 5% acrylamide gel and were then eluted from the gel into elution buffer (from RPA II kit, Ambion, Inc.). These probes were used in solution hybridization procedures with 20 ug of rat lung RNA or 30 ug of penis RNA using the manufacturer's recommendations provided in the RNase assay kit (RPA II, Ambion, Inc.) overnight. Hybridized specimens were digested with a nuclease cocktail provided in the RPA II kit and the digests were subsequently analyzed by electrophoresis on 5% acrylamide sequencing gels adjacent to molecular weight marker lanes.

Some control reactions included labeled probes hybridized with yeast RNA (20ug) (with/without RNase digestion). Gels were exposed to Kodak XAR-5 film to produce an autoradiograph showing the presence of RNase-protected bands.

B. Results and Discussion

Erectile dysfunction is often associated with problems in vascular perfusion to the erectile components of the penis. In order to better understand the factors that control vascular formation and perfusion in the erectile tissues of the penis, we have begun to characterize the expression of vascular endothelial growth factor (VEGF) in penis tissues.

5 VEGF is one of several polypeptides that has significant
angiogenic activity in vitro and in vivo. Extensive
characterization of the VEGF gene and its products has shown
10 that several different mature mRNA transcripts exist,
5 originating from alternative splicing of the basic VEGF
transcript. These variant transcripts can encode peptides
with different biological activities.

15 Penile tissue was obtained from adult rats and from human
10 patients undergoing penile prosthesis implantation. Analysis
of the forms of VEGF transcripts was performed using a
reverse transcriptase-polymerase chain reaction (RT-PCR)
20 technique with primer pairs derived from the first and eight
exon of the VEGF gene. The expression levels of the various
15 isoforms in the rat penis were then quantified using RNase
Protection Assays. Four previously described splice
25 variants of VEGF mRNA (VEGF 120,144,164,188) were detected
in rat and human penile tissues. In contrast to rat lung
where the most abundant form of VEGF mRNA is the 188 splice
20 isoform, VEGF 164 is the most abundant transcript detected
30 in the penis. Finally, sequence analysis of numerous VEGF
cDNA clones obtained from rat penis demonstrated the presence
of a previously undescribed VEGF splice variant that could
give rise to a protein of 110 amino acid residues (VEGF 110,
35 25 GenBank accession number AF080594³). In summary, a number of
VEGF mRNA isoforms are expressed in the rat and human penis
with the splice variant encoding a 164 amino acid protein
present in greatest abundance. This study is a prelude for
40 attempts to genetically manipulate VEGF expression in the
30 penis as a therapy for erectile dysfunction.

45 1. RT-PCR Analysis of VEGF mRNA Splice Variant Expression
in Rat and Human Penis

35 The mammalian VEGF gene [29] is known to consist of at least
8 exons that can be assembled, through alternative splicing
50 [30-32], into a number of variant mRNA molecules that have
the potential to encode differing proteins, each having

mitogenic activity for the endothelial cell [33,34]. Both human and rodent cell lines and tissues have been characterized for the expression of these VEGF splice variants and the prominent forms found in adult tissues include transcripts that can encode for 121, 165 or 189 amino acid (AA) containing proteins (in humans) [35-38]. Other VEGF splice variants have been detected in much lower abundance, for example, a 145 AA- encoding transcript for VEGF has been found in human uterine and placental tissue [39-41] as well as a 206 AA -encoding transcript that was found in fetal liver and placenta [41,42]. Of this group of VEGF splice variants, all transcripts contain the first five VEGF exons as well as the last (eighth) exon but differ in the inclusion and/or arrangement of the sixth and seventh exon. Virtually identical VEGF splice variants have also been described in rodent tissues, however the variant rodent VEGF transcripts generally encode for a protein product containing one amino acid less than the human counterpart (see Figure 1) [28,43]. Using a RT-PCR screening method, we attempted to identify the VEGF mRNA splice variants that are expressed in rat and human penile tissues. Oligonucleotide primers designed to amplify cDNA from the first to the eighth exon of rat VEGF were used in a PCR amplification reaction of cDNA made from RNA extracted from rat lung or from rat penis. The RT-PCR amplification products were examined by electrophoresis on an agarose gel followed by ethidium bromide staining. As expected (Figure 2A), these primers amplified three distinct cDNA fragments of 564, 492 and 360 bp in size from the rat lung cDNA (corresponding to the expected 188, 164 and 120 rat VEGF AA-encoding isoforms) as well as a distinct cDNA fragment of 432 bp. All of these cDNA fragments were also amplified from the cDNA of rat penis. Although the RT-PCR screening method was not designed to be quantitative, there appeared to be a distinct difference in the abundance of these RT-PCR Products between rat lung and penis tissue. The most predominant of the VEGF cDNAs amplified from lung RNA encoded the 188 AA isoform of VEGF whereas the most predominant transcript amplified from penis RNA appeared to

5 be the one encoding the 164 AA isoform of VEGF (Figure 2A).
Each of these cDNA fragments was individually cloned into
10 plasmids so that they could be sequenced and confirmed as
VEGF splice variants. The sequencing confirmed our
5 identification of the 188, 164 and 120 AA forms as well as
confirmed that the 432 bp amplification product was the VEGF
transcript variant encoding the 144 AA form of VEGF that was
15 previously found only in uterine and placental tissues. More
surprisingly in our survey of the cDNA clones resulting from
20 RT-PCR amplification, we found one cDNA clone (330 bp)
containing a novel splice variant of VEGF A that has never
before been described (see Figure 1). This splice variant
25 contained the entire first three exons of rat VEGF-A spliced
to a partial exon 7 (now referred to as exon 7B) and was
terminated by the entire exon 8. It is likely that the
partial exon 7 included in this novel transcript (7B) was
30 another of the many splice adoptions of the VEGF A transcript
since a canonical splice donor sequence (CCGCAG/) [44] was
present at the end of the region of exon 7A that was deleted
from this particular splice variant. Although this splice
variant must be present in much lower abundance than any of
the better known forms, this novel VEGF A splice variant does
have the potential to encode a 110 amino acids isoform of
VEGF- A.

35 25 Similar primer sets were utilized to amplify cDNA that was
reverse transcribed from human penis RNA and from RNA
40 extracted from a human prostate cancer cell line, LNCaP, that
is known to express VEGF-A in abundance. Figure 2B shows the
30 ethidium bromide stained agarose gel on which the
amplification products from human penis cDNA, LNCaP cell cDNA
or rat tissue (penis and lung) cDNA were electrophoresed.
45 As can be seen from the results shown here, human penis (and
human LNCaP cells) expresses the identical repertoire of VEGF
35 splice variant isoforms that were found in the rat penis
(including the 189, 165, 145 and 121 AA encoding isoforms).
50 Moreover, these isoforms were present in similar abundance
to the rat penis isoforms.

2. RNase Protection Assay to Confirm Relative Abundance
of VEGF A Transcripts in Rat Penis

In order to confirm and better quantify that the predominant
5 VEGF-A transcript splice variants expressed in rat penis
differed significantly in abundance from the forms expressed
in rat lung, we developed an RNase protection assay that
would allow us to distinguish the relative abundance of the
15 different rat VEGF-A splice variants in RNA samples.
10 ³²P-radiolabeled probes for the 188 AA or the 164 AA splice
variant of rat VEGF A cDNA were prepared by in vitro
transcription of expression plasmids containing these
respective cDNA inserts. The probes were individually
20 hybridized to RNAs extracted from rat lung or rat penis and
15 were then digested with a nuclease cocktail and
electrophoresed on a polyacrylamide gel. The gel was exposed
25 to film for autoradiography and the signal intensity of the
protected fragments on this assay demonstrates the relative
abundance of the corresponding transcript.

20 This two-probe assay was designed to demonstrate the presence
of the VEGF isoforms through the detection of certain
"diagnostic" fragments. For example, when using the larger
transcript as a probe (the 188 splice isoform), the presence
35 25 of a protected fragment at 564 bp would distinguish and
confirm the presence of the 188 splice variant in the test
mRNA specimen whereas the presence of a protected 150 bp
fragment in the digest would distinguish the presence of the
40 164 splice variant (see Diagram at lower part of Figure 3A).
30 Likewise, when using the smaller transcript as a probe (164
splice isoform), the presence of a protected fragment of 492
bp would confirm the presence of the 164 splice variant in
45 the test specimen (See Diagram at lower part of Figure 3B).

35 The results (Figures 3A and 3B) of this RNase protection
assay showed that, in rat lung, the most abundant splice
50 variants of VEGF-A mRNA are for the 188 and the 164 isoforms,
confirming the earlier experiment involving RT-PCR

5 amplification of VEGF A isoforms (Figure 2A/2B) as well as
other reports [39]. In rat penis mRNA, we did not observe
10 significant protection of a 564 bp fragment nor the 414 bp
fragment using the larger splice isoform probe, indicating
5 a much lower abundance of the 188 splice variant mRNA in
penis mRNA compared to lung as well as a low abundance of the
144 splice variant in penis mRNA. With the smaller transcript
as a probe, we were able to identify the presence of
15 protected fragments at 492 bp and 342 bp, confirming the more
10 abundant presence of the 164 and 120 isoform splice variants
in penis mRNA. Again, this observation supports the RT-PCR
experiments on rat penis in which we found that the 164 and
20 120 splice isoforms appeared to be the most abundant VEGF
splice variants present in rat penis mRNA (Figure 2A/2B).

15

25 3. Expression of VEGF Splice Variants 144/145 and 205/206
in Adult Male Tissues

A standard RT-PCR technique was used to detect VEGF splice
isoforms. Using an upstream primer starting in VEGF exon 1
20 and a downstream primer from VEGF exon 8, RT-PCR was
performed on RNAs extracted from mature rat lung and penis
30 as well as from a human prostate cancer cell line LNCaP. When
the RT-PCR reaction products were analyzed by agarose gel
electrophoresis, 4 major bands were detected from each of the
35 reactions (Figure 4). The size of 3 of these bands (at
360/363, 492/495 and 564/567 basepairs (rat/human)) would
correspond to the expected transcript sizes encoding the
120/121, 164/165, and 188/189 AA isoforms of VEGF-A. However,
40 an additional band at 432/435 bp, clearly visible in the
30 reaction products from rat lung/penis and human penis/LNCaP
cells, would more correspond with the expected size of the
144/145 splice form of VEGF-A (Figure 4), previously only
45 detected in placental and uterine tissues (sheep and humans)
(41,42,39) and in cultured human endometrial carcinoma cells
35 (39). The amplification products from these reactions were
individually cloned into plasmid sequencing vectors and were
sequenced. The sequences obtained confirmed our
50 identification of the 120/121, 165/165, and 188/189 AA splice

5 isoforms as well as the presence of the supposedly more rare
144/145 splice variant in the RNAa from these cells/tissues.

10 In the results of the previous RT-PCR reaction, we did not
5 find the clear presence of a larger, 615 bp product, that
would have resulted from the corresponding amplification of
the VEGF-A splice isoform encoding a 205/206 AA peptide.
15 However, the RT-PCR reaction was subsequently repeated using
the same upstream primer (starting from exon 1) with a
10 different downstream primer, (complimentary to the last five
bases of exon 6A and continuing into the first 19 bases of
exon 6B). The 6B exon of VEGF-A is found only in the VEGF
20 205/206 splice isoform, therefore this second primerpair was
designed to selectively amplify the other supposedly rare
15 isoform, VEGF 205. The application of this second primer pair
showed a band at 433 basepairs in the amplification products
from RNAs extracted from rat lung and penis (Figure 5), a
25 size that would be expected if the VEGF 205/206 splice
isoform was present in the RNAs. The identity of this
20 fragment was also confirmed, at least for the rat lung, by
cloning and sequencing the 433 bp amplification product. This
30 sequence showed complete homology to the rat VEGF-205 mRNA
splice variant.

35 In conclusion, these results indicate that the rarer splice
variants of VEGF-A (encoding the 144/145 and 205/206 AA
forms) are probably more widely expressed in adult rat and
human tissues than previously suspected. The PCR reaction
40 conditions under which these rare splice variants of VEGF
30 were detected were not so vigorous as to amplify such rare
transcripts as those referred to as "basal" in nature.
Although the transcript encoding the 144/145 splice variant
was seemingly amplified less than the 120/121, 164/154, or
45 188/189 variants, it was well within detection limits of
35 simple DNA staining techniques. However, the apparently lower
abundance expression of VEGF 144/145 and 205/206 in these
tissues (when compared to the more predominant VEGF splice
50 variants) probably explains the failure of other

investigators to identify their presence, especially in tissues that have been subject to repeated VEGF mRNA characterization, such as lung.

Experimental Discussion

Erectile function is dependent on the development of an appropriate penile vasculature and maintenance of an effective blood supply to the erectile tissues of the penis. The development and growth of a vascular system is referred to as angiogenesis and vasculogenesis. These processes are governed by several types of growth factors, including basic FGF (bFGF) and VEGF. Previously, we described the abundant presence of a heparin-binding growth factor in rat penis that had a functional activity that could be neutralized by antibodies to bFGF, suggesting that this substance was indeed bFGF [45]. Here we characterized the mRNA of rat and human penis to evaluate whether any of the many mRNA splice isoforms of VEGF are expressed in penile tissues and to determine which of the multiple splice isoforms might be the most abundantly expressed in the penis.

These results show that several different mRNA splice variants of VEGF-A mRNA are expressed in both rat and human penis and that there appears to be a distinct difference in the abundance of the different VEGF-A splice isoforms when compared to another rat tissue (rat lung) in which VEGF-A expression is known to be abundant. Whereas it has been confirmed that the rat lung expresses most abundantly an mRNA encoding the 188 splice variant, the rat penis, in contrast, expresses the 164 splice variant of VEGF-A mRNA at greatest abundance. Other VEGF splice variants, including the previously described 120 splice variant are also expressed at much lower levels by the lung and the penis. The ability to detect the presence of the 144 VEGF-A splice variant which was previously found only in placenta and some female reproductive tissues (uterus) was also surprising [39-42].

Moreover, the sequencing studies of a large number of VEGF cDNAs that were obtained following RT-PCR amplification of rat penis mRNA revealed the presence of a new splice variant of VEGF-A which has the more unusual characteristic of retaining the first 3 exons (instead of the first 5) as well as having an apparent splice within the 7th exon. This splice variant is likely to be present in extremely low abundance, as we never detected a significant 330 bp amplification product in our RT-PCR experiments, nor was the corresponding protected exon fragments in our RNase protection experiments ever found. While the possibility was considered that this unusual splice variant of VEGF might not be able to produce an angiogenic peptide, it is of interest that another rare splice variant of (mouse) VEGF mRNA has also been described, containing only the first three exons of VEGF. This splice variant (VEGF 115) has been shown to encode a peptide that is able to bind to VEGF receptor and activate mitogenesis of endothelial cells [46]. Therefore, the unusual VEGF splice variant (VEGF 110) observed in these studies, although seemingly rare and low in abundance, probably has the potential to produce a functional VEGF peptide.

The recent approval by the FDA of Sildenafil citrate as the first oral therapy for erectile dysfunction has become a landmark for the development of pharmacotherapy for erectile dysfunction. However, all current pharmacologic treatments of erectile dysfunction consist of "on-demand" medications that produce temporary erections. At this time there is no curative treatment for erectile dysfunction. The work in this project is based on our conceptualization of the induction of vasculogenesis in the erectile tissue as a potential cure for the reduction of vascular elements frequently encountered in vasculogenic erectile dysfunction. In this descriptive study, VEGF-A mRNA expression was surveyed in rodent and human penis. The present characterization of the various VEGF isoforms in the erectile tissues is motivated by our interest in defining the angiogenic growth factors that regulate

5 penile vasculogenesis and potentially exploiting these
findings for therapeutic applications to treat human
impotence. One could conceivably consider the therapeutic
10 application of VEGF peptides to stimulate further penile
5 vascular development as has been contemplated for other
vascular insufficiency conditions [9,23]. Likewise, use of
VEGF expression vectors provides a novel gene therapeutic
15 approach for the curative treatment of erectile dysfunction,
an approach that is being contemplated for other gene
10 products involved in the response [47,48]. By identifying the
predominant angiogenic peptides naturally expressed in the
erectile tissues of the penis, this goal is one step closer.

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5 growth factor (-1, platelet-derived endothelial cell growth
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40 30

Claims

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What is claimed:

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1. A method of increasing or maintaining the blood supply in the penis of a male subject which comprises administering to the subject an amount of vascular endothelial growth factor effective to increase or maintain the blood supply in the subject's penis.

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2. A method of treating erectile dysfunction in a subject which comprises administering to the subject an amount of vascular endothelial growth factor effective to increase the blood supply in the subject's penis and thereby treat the subject's erectile dysfunction.

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3. A method of increasing or maintaining the density of vascular structures in the penis of a male subject which comprises administering to the subject an amount of vascular endothelial growth factor effective to increase or maintain the blood supply in the subject's penis.

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4. The method of claim 1, 2 or 3, wherein the vascular endothelial growth factor is VEGF-A 205/206, VEGF-A 188/189, VEGF-A 164/165, VEGF-A 144/145, VEGF-A 120/121, or VEGF-A 110.

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5. The method of claim 1, 2 or 3, wherein the vascular endothelial growth factor is administered intravenously, topically, transdermally, orally or by injection.

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6. The method of claim 1, 2 or 3, wherein the vascular endothelial growth factor is injected into the penis.

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7. The method of claim 1, 2 or 3, wherein the vascular endothelial growth factor is injected into corpora cavernosa tissue.

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8. The method of claim 1, 2 or 3, wherein the vascular endothelial growth factor is injected into corpus spongiosum tissue.

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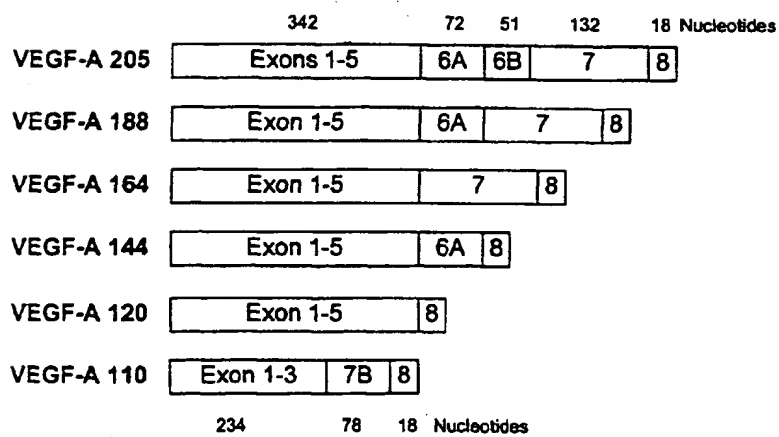
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9. A method of increasing or maintaining the blood supply in the penis of a subject which comprises introducing a nucleic acid comprising a gene encoding a vascular endothelial growth factor into a suitable cell under conditions such that the nucleic acid expresses vascular endothelial growth factor so as to thereby increase or maintain the blood supply in the subject's penis.
10. The method of claim 8, wherein the nucleic acid comprises a vector.
11. A method of increasing or maintaining the blood supply in the genital area of a female subject which comprises administering to the subject an amount of vascular endothelial growth factor effective to increase or maintain the blood supply in the subject's genital area.

1/7

FIGURE 1

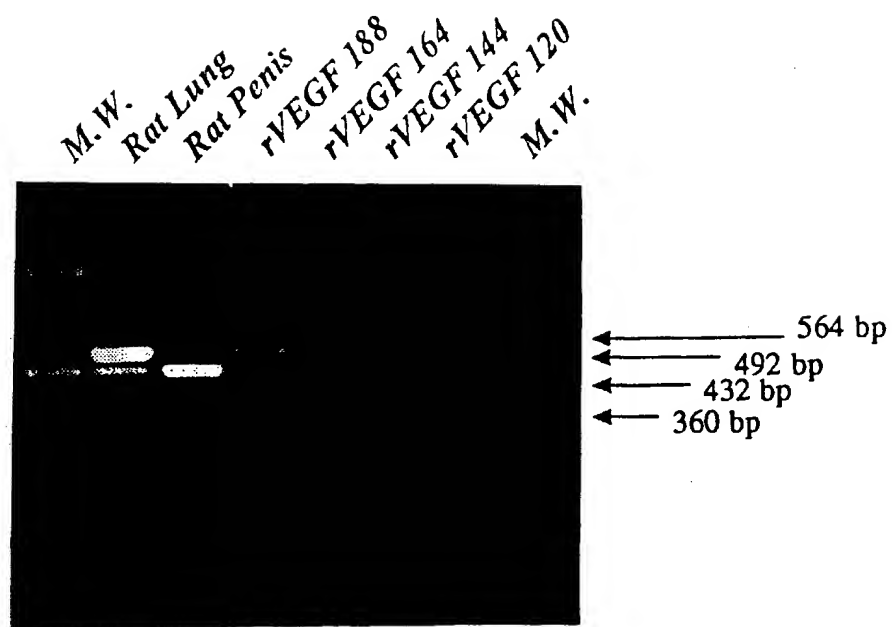
VEGF-A TRANSCRIPT SPLICE VARIANTS



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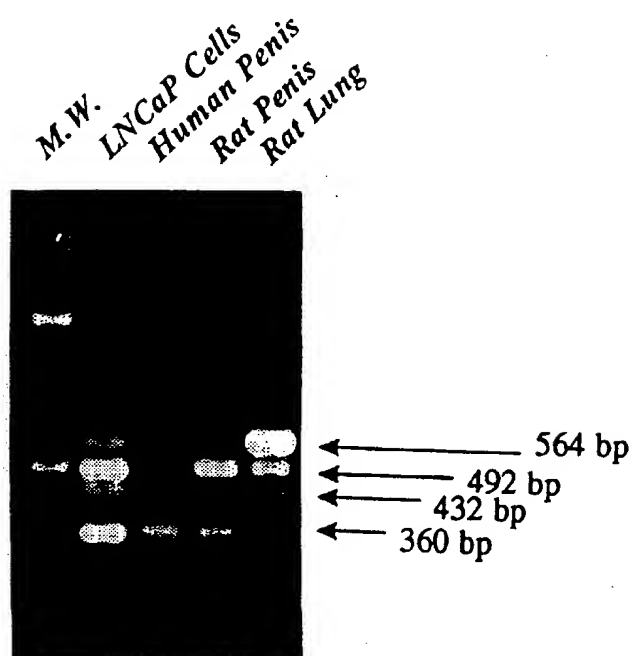
2/7

FIGURE 2A



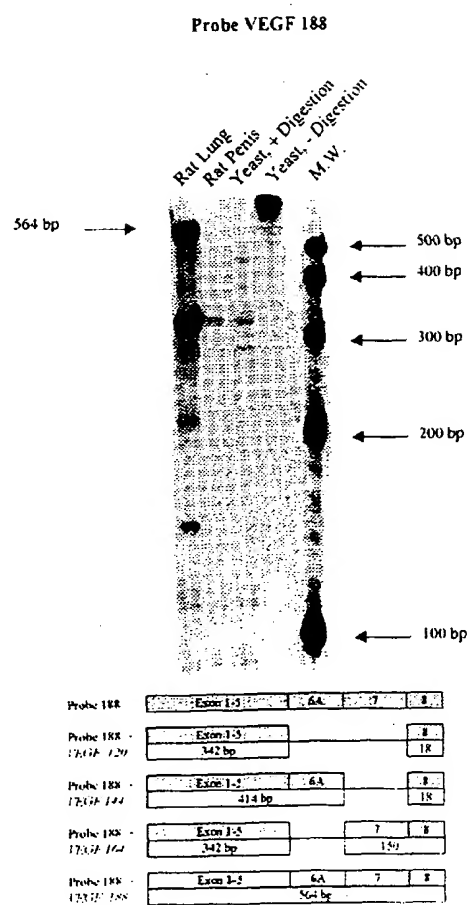
3/7

FIGURE 2B



4/7

FIGURE 3A

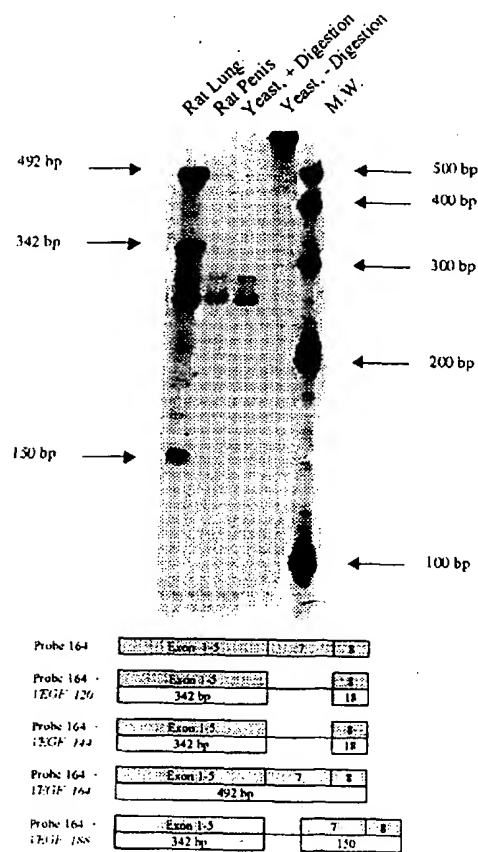


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FIGURE 3B

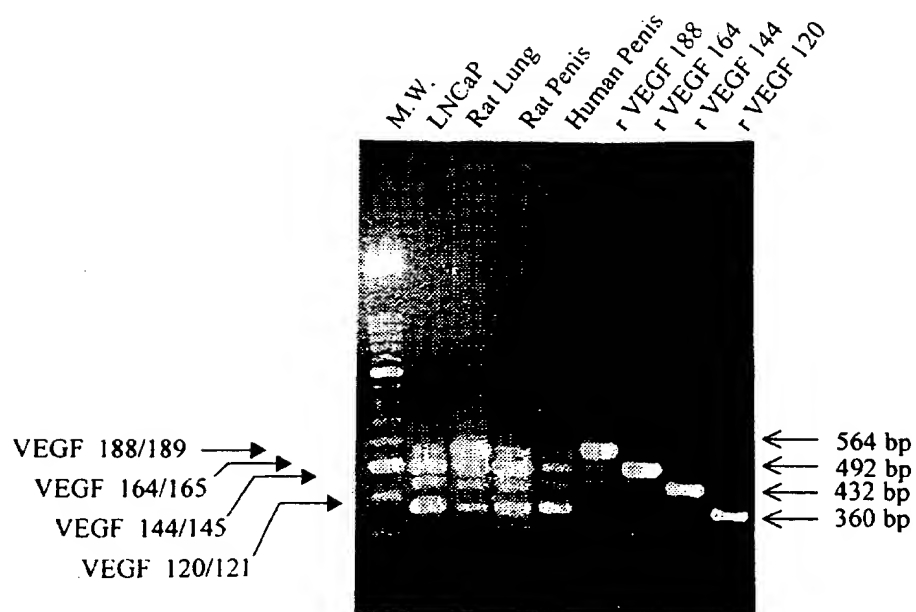
Probe VEGF 164



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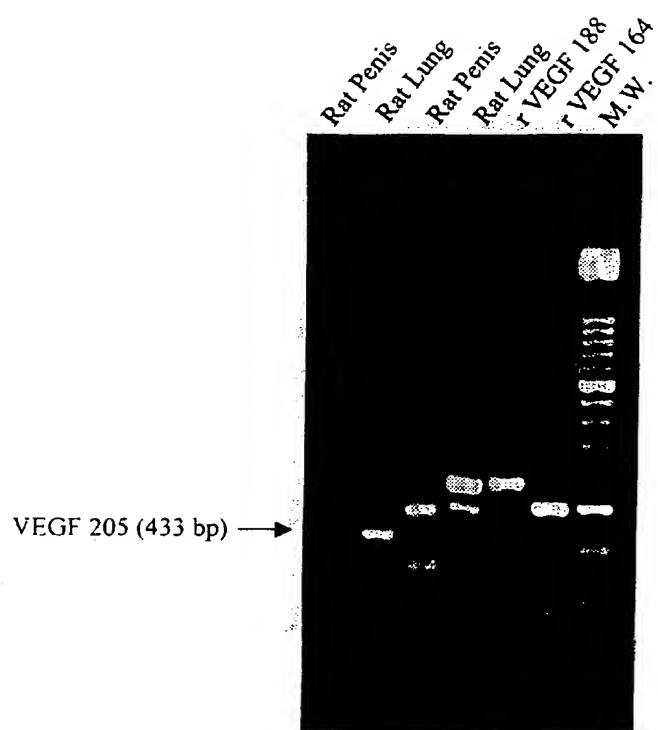
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FIGURE 4



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FIGURE 5



INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/01535

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) :A61K 38/00, 38/24, 38/27
US CL :514/12; 530/399

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 514/12; 530/399

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
none

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

caplus, uspatfull
vegf, vascular endothelial growth factors, erection, impotence, erectile dysfunction

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y, P	WO 99/56785 A2 (UNIVERSITY OF PITTSBURGH) 11 November 1999 (11-11-99), see entire document.	1-11
A,P	WO 99/60630 A1 (GLAXO GROUP LIMITED) 25 November 1999 (25-11-99), see entire document.	1-11

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:	*T* later documents published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
A document defining the general state of the art which is not considered to be of particular relevance	*X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
B earlier document published on or after the international filing date	*Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
L document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	*A* document member of the same patent family
O document referring to an oral disclosure, use, exhibition or other means	
P document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

24 APRIL 2000

Date of mailing of the international search report

16 MAY 2000

Name and mailing address of the ISA/US
Commissioner of Patents and Trademarks
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